New Satellite Energy Balance and Water Cycle Products for the Study of Interactions between Atmospheric Hydrology and the Earth's Radiation Budget

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Project statement: This project will provide energy budget and hydrologic cycle datasets from the observations of TRMM, Aqua, and CloudSat, and, through their subsequent analysis, yield insights into the fundamental relationships between radiation, clouds, and precipitation on scales ranging from the mesoscale to those representative of global circulations.

Objectives & deliverables:

- Multi-year radiative flux and heating rate dataset over tropical oceans from TRMM observations (with associated high/low cloud and precipitation fields)
- Two-year A-Train-based dataset with coverage extended to mid-latitude/land using MODIS/AMSR-E/CloudSat
- Rigorous evaluation of uncertainties in these and similar products through: (a) product inter-comparisons, (b) error budget analyses of component algorithms
- Insights into fundamental relationships in these datasets between atmospheric heating and atmospheric components of the water cycle (i.e. clouds and precipitation) through comprehensive statistical analysis on different space/time scales

Technical Approach – Three Phases:

1. **Generate datasets**
   a) use VIS/IR/PMW radiance observations to retrieve the three-dimensional structure of clouds, precipitation, etc. in the atmosphere
   b) use this as input to broadband radiative transfer model to compute radiative fluxes and atmospheric heating rates

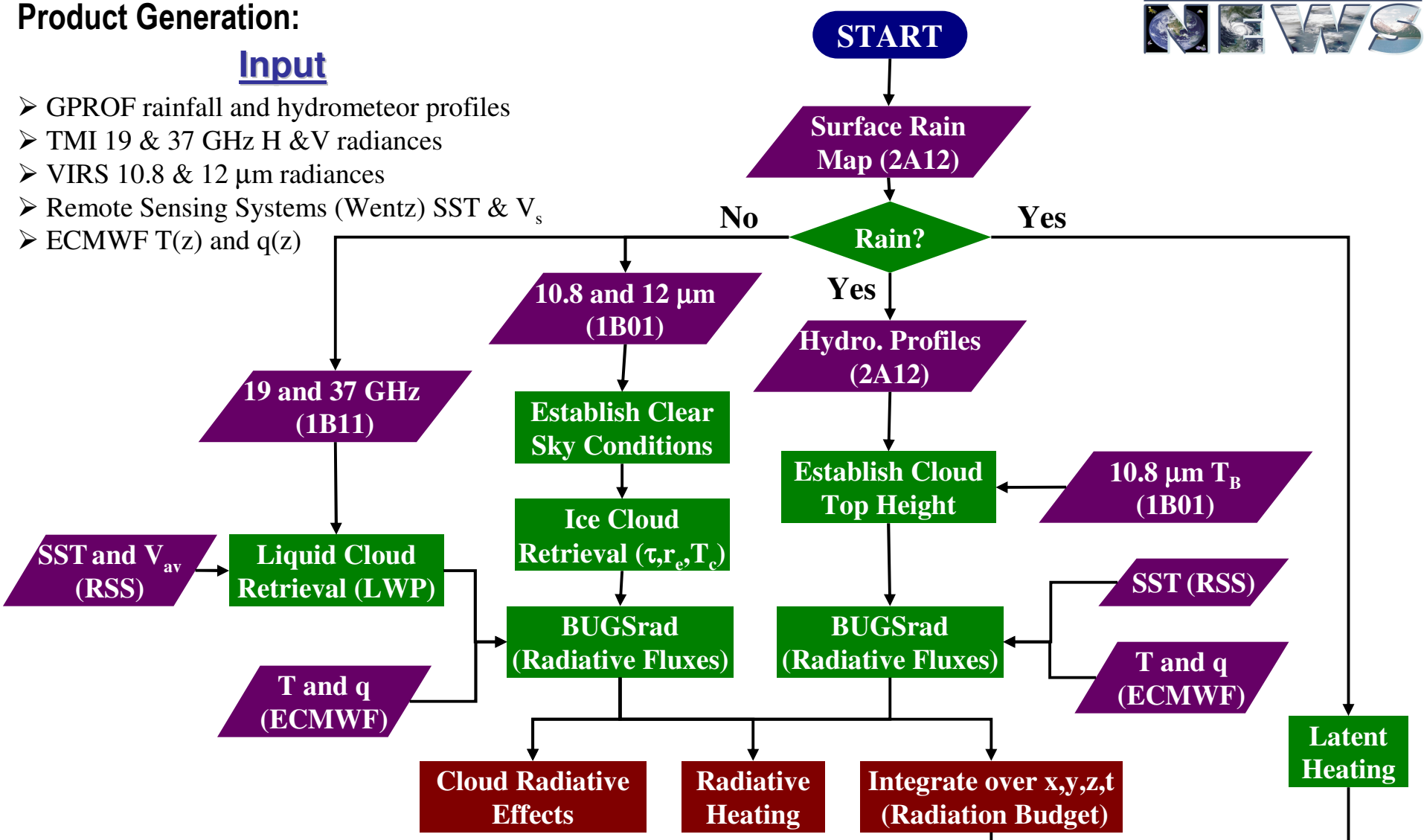
2. **Evaluate products and establish baseline error bars for satellite-based radiative flux estimates in general**
   a) Refine error budgets of algorithms that form the basis of the technique
   b) Assess the quality of these error estimates using comparisons with surface observations and similar products
   c) Determine dominant sources of error and areas in need of improvement

3. **Explore linkages between energy budget and water cycle through statistical analysis of the resulting datasets**

Product Generation:

Input

- GPROF rainfall and hydrometeor profiles
- TMI 19 & 37 GHz H &V radiances
- VIRS 10.8 & 12 μm radiances
- Remote Sensing Systems (Wentz) SST & V_s
- ECMWF T(z) and q(z)

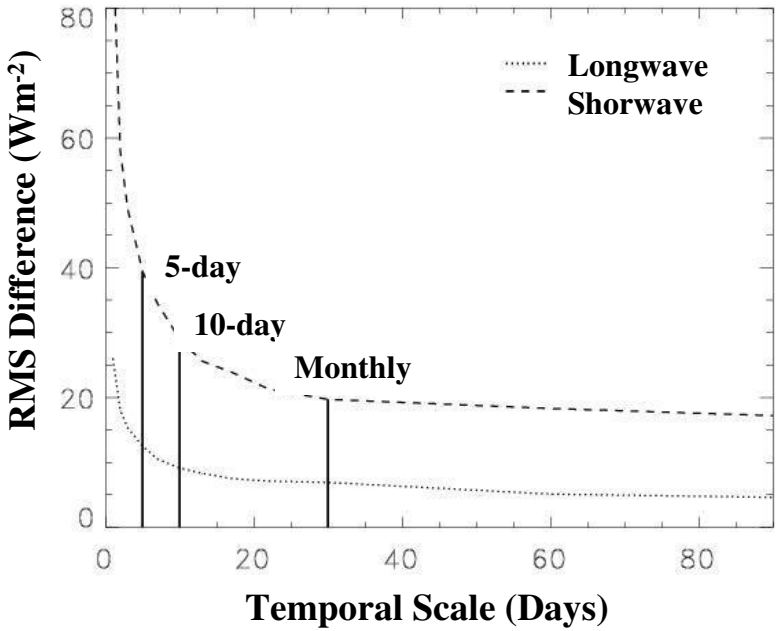


Output

- distribution of rainfall and cloud over tropical oceans
- column-integrated latent heating over tropical oceans
- up- and downwelling longwave and shortwave flux profiles
- longwave, shortwave, and net heating rate profiles

Product Evaluation – TOA flux example:

Comparison with CERES Obs.



- LW flux errors range from 25 Wm^{-2} instantaneous to 5 Wm^{-2} on seasonal timescales
- SW flux errors range from 80 Wm^{-2} instantaneous to 20 Wm^{-2} on seasonal timescales

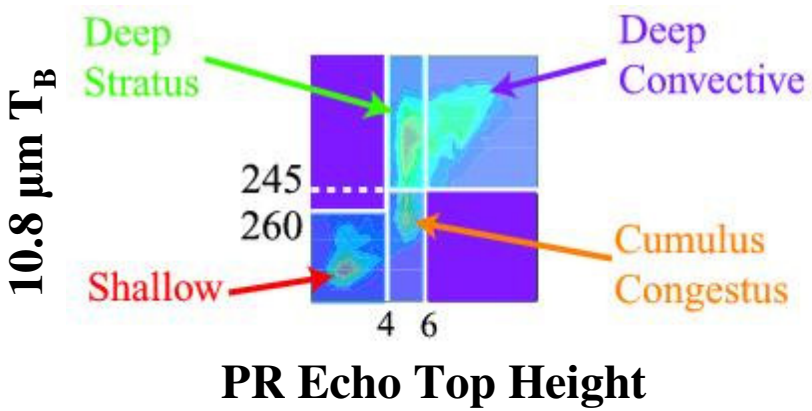
Sensitivity Studies

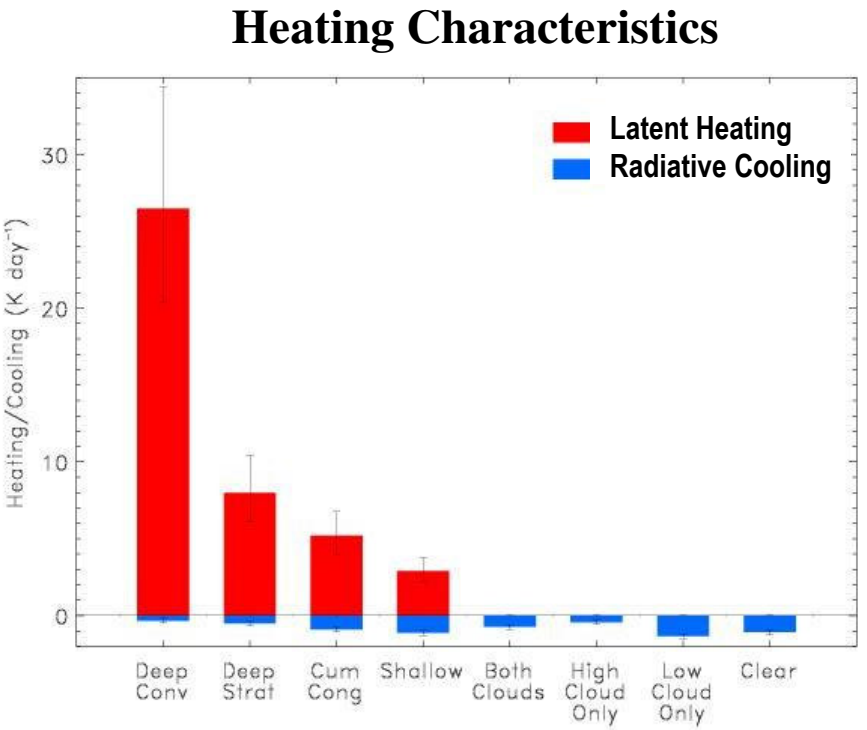
1. Longwave: errors ~ 10 Wm^{-2} on monthly timescales primarily due to uncertainties in ice cloud temperature and water vapor profile

2. Shortwave: errors ~25 Wm^{-2} on monthly timescales primarily due to liquid cloud detection, water path, and particle size.

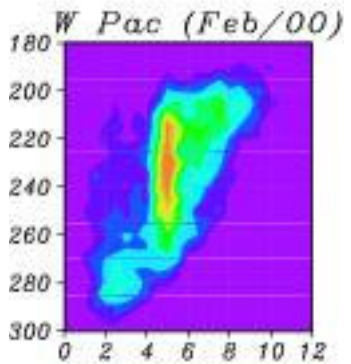
Assessing Cloud Impacts on Atmospheric Heating:

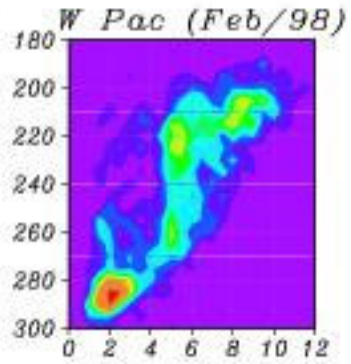
- General goal: statistically compare components of the atmospheric energy budget and hydrologic cycle with an emphasis on determining the impacts of clouds and precipitation on atmospheric heating
- Eg 1: develop objective observationally-based cloud/precipitation classification scheme for identifying and distinguishing climate regimes



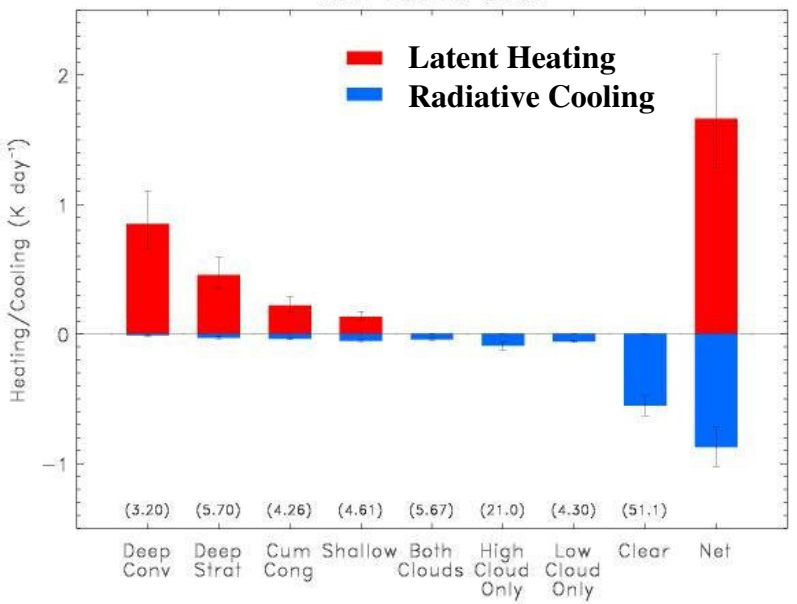


Heating Regimes in the Tropical West Pacific

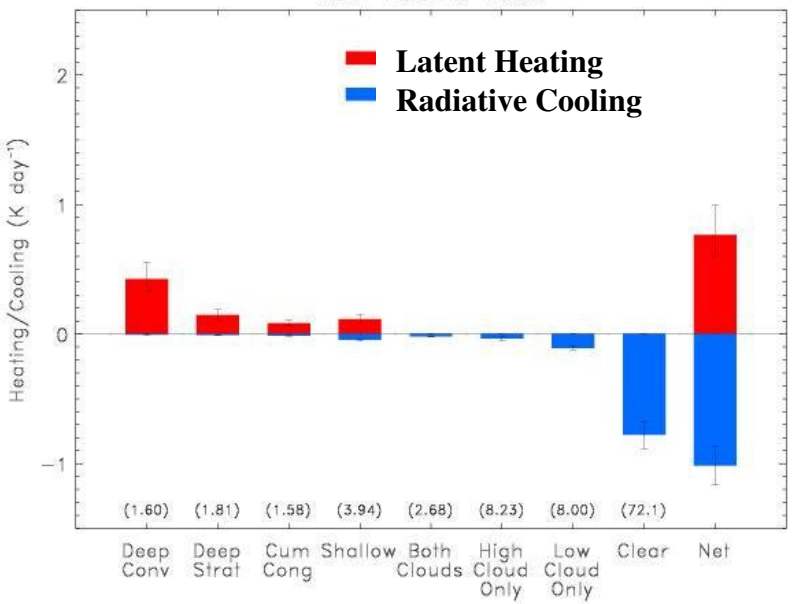




February 2000



February 1998



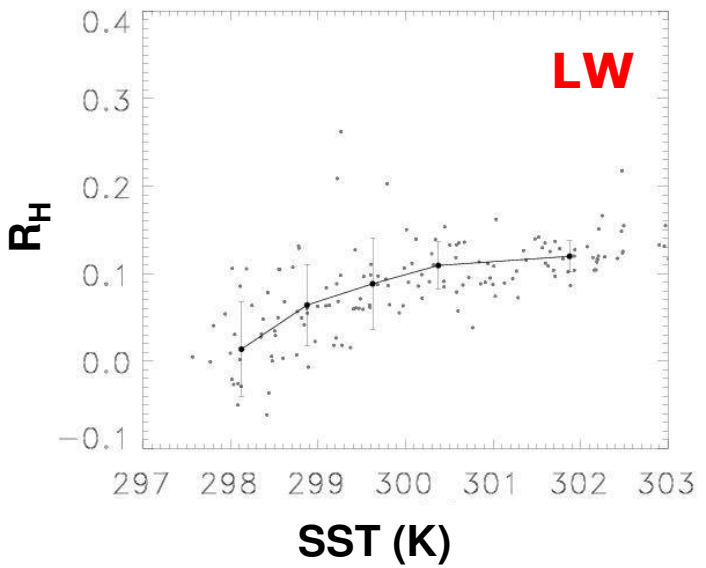
"Normal Year"

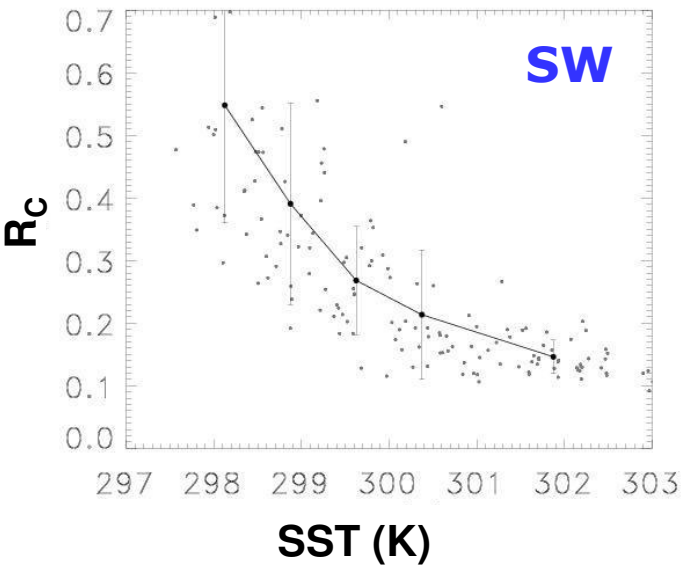
"El Niño Year"

Assessing Cloud Impacts on Atmospheric Heating continued:

- Eg. 2: Quantify relationships between energy balance and hydrology on a variety of scales

Radiative heating "efficiencies" as a function of SST. R is defined as the ratio of atmospheric radiative heating (h) and surface cooling (c) to surface rainfall rate.





*10º/twenty-day bins in TWP

Data set needs (uncompressed size estimates included)**:**

- VIS/IR: (a) TRMM 1B01 (VIRS radiances **~1.5 GB/day**) and (b) MODIS MOD02 (radiances) or MOD06 (cloud product **~4 GB/day**)
- PMW: (a) TRMM 1B11 (TMI radiances **~200 MB/day**) and 2A12 (TMI-based rainfall estimates **~1.5 GB/day**), (b) AMSR-E L2A radiances and L2B rainfall products **(smaller)**, and (c) Remote Sensing Systems (F. Wentz) SST, CWV, and surface wind speed products from TMI and AMSR-E **(smaller)**
- Radar: CloudSat 2B-LWC, 2B-IWC, and 2B-FLXHR products **~4 GB/day**
- ECMWF/NCEP reanalysis T(z), q(z) **(smaller)**

Project outputs (uncompressed size estimates included)**:**

- Orbit-level or Daily TRMM-based radiative fluxes, clouds, and rainfall estimates
- Orbit-level or Daily A-Train-based radiative fluxes, clouds, and rainfall estimates

Anticipate **~200 MB/day** at 0.25^{o} resolution or **15 MB/day** at 1^{o} resolution.

Potential collaborations (with NSIT, other NEWS projects, etc.) **:**

- Evaluation of products: Wielicki, Fetzer, Rossow
- Latent heating profiles: Olson
- Model evaluation: Soden
- Land surface properties: Rodell, Reichle, Hornbuckle
- Water cycle: Wentz, Roads, Fetzer, Sorooshian

Important outside linkages/resources (outside the NEWS team) **:**

- Precipitation Measurement Missions (TRMM/GPM) science team (evaluation of TRMM rainfall products - Berg/Kummerow)
- CloudSat science team/SDPWG (cloud/light rainfall/snowfall)
- CALIPSO science team (aerosol)
- ARM (ground-based observations)
- NASA Multi-disciplinary Research (multi-scale modeling framework (MMF) evaluation - Luo)

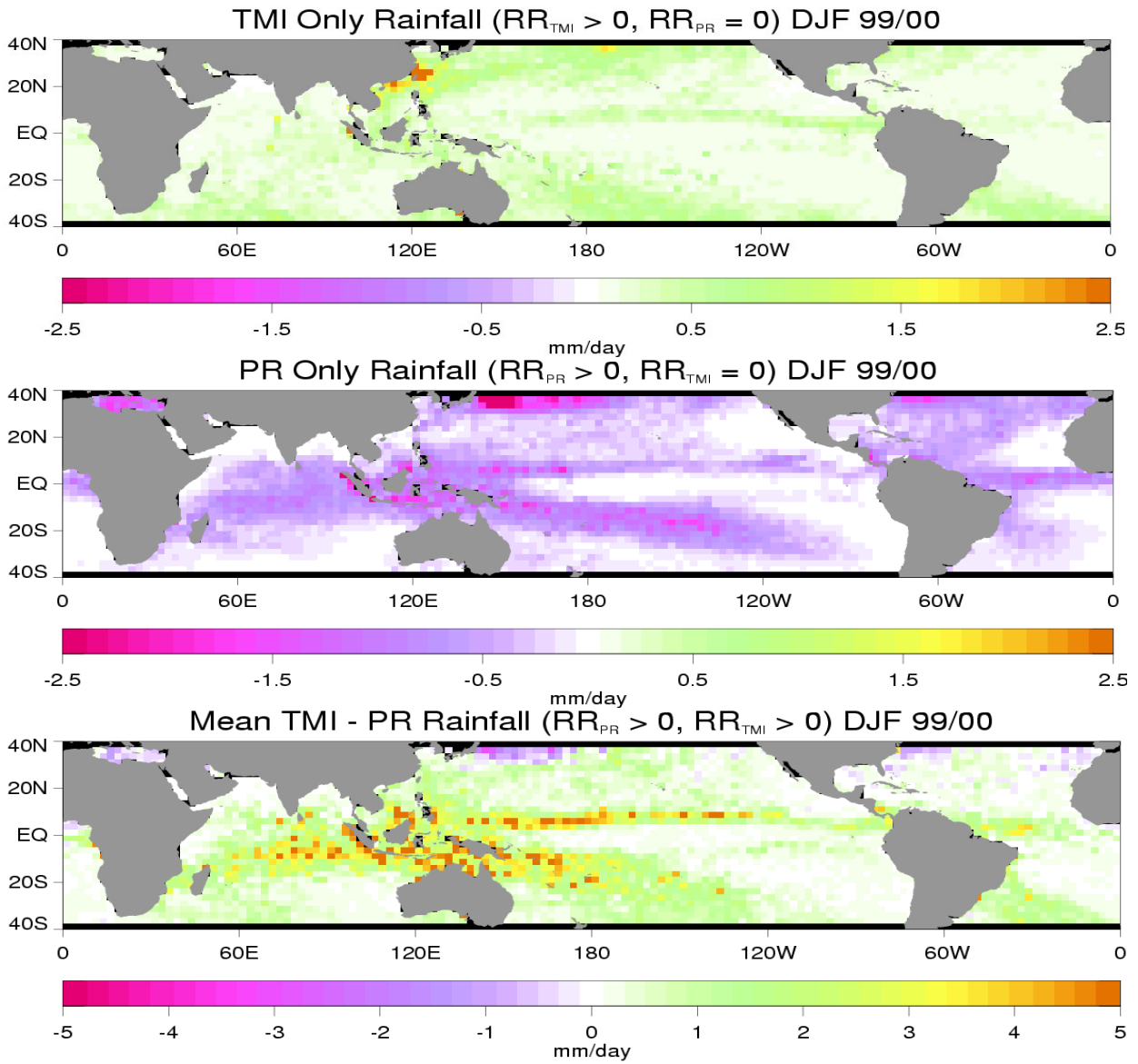
Expected contribution to the NEWS objective:

- Two new multi-satellite/multi-sensor datasets at the intersection between atmospheric energy balance and the global water cycle from TRMM and A-Train observations
- Baseline error estimates for current satellite-based estimates of atmospheric radiative flux products for model evaluation/data assimilation applications
- Advance our understanding of the role of clouds in modifying atmospheric heating with a direct link to precipitation processes through the direct inclusion of passive microwave-based rainfall and latent heating estimates

Issues, needs, and concerns:

- Water vapor, surface temperature/emissivity/albedo, cloud, and precipitation datasets over land/ice backgrounds
- Frozen precipitation

Biases in TRMM Rainfall Products



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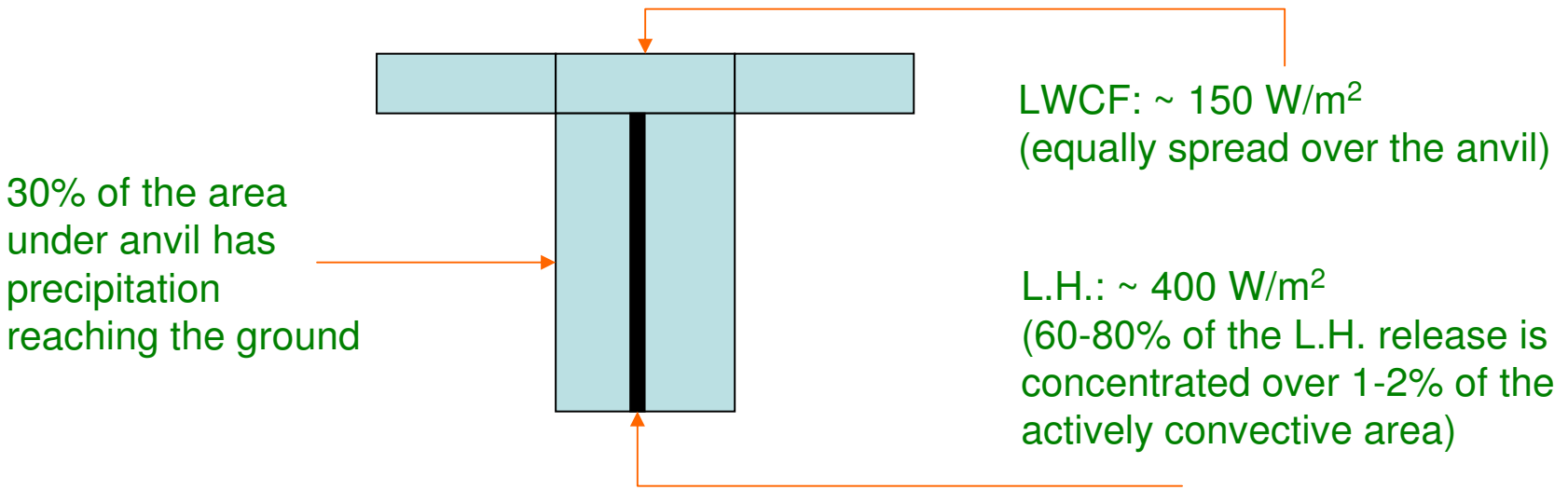
MCS Heating within a Multi-scale Model Framework (Luo)

- Statistical analysis of high resolution cloud and precipitation information from the embedded CRM indicates the following mean properties:



- These results can, in principle, be directly compared with observations to evaluate its representation of the influence of such systems on atmospheric heating.